Experiments for Heat Transfer Diagnostics: IR Emissivity Issues

ALPS e-Meeting

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Measurement and interpretation of surface temperatures of low emissivity surfaces is by no means straightforward.

Objective: Develop working systems to measure the surface temperatures of flowing liquid surfaces.

- ✓ **measure surface temperatures in static liquid metal pools; identify issues and develop useful techniques**
- **build and operate a flowing liquid (Li) metal loop**
- **measure surface temperatures of flowing liquid metal**
- **collaborate with others on heat transfer experiments**
- **collaborate with others in preparing LM modules for experiments in confinement devices (NSTX, C-MOD,..)**

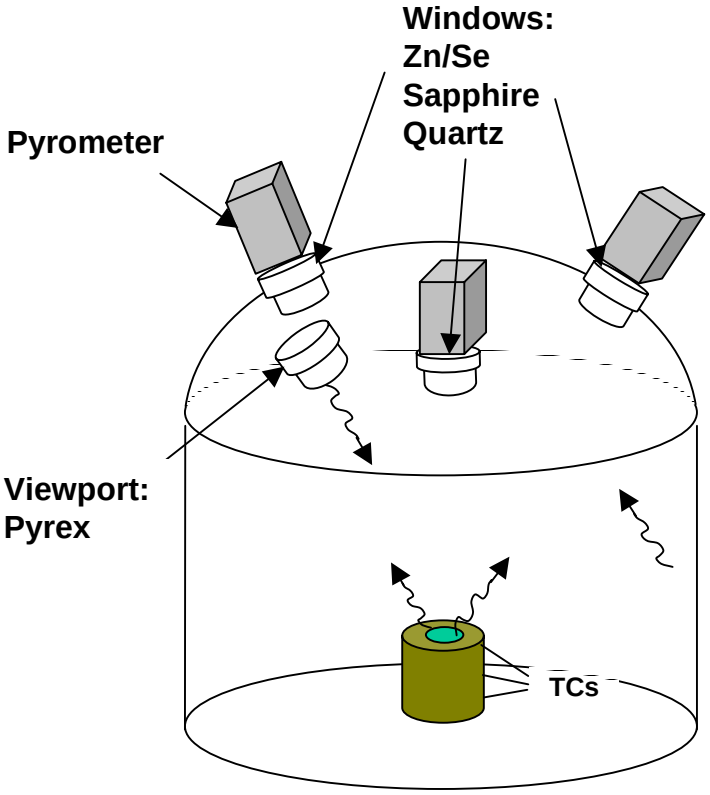
IR diagnostic error sources

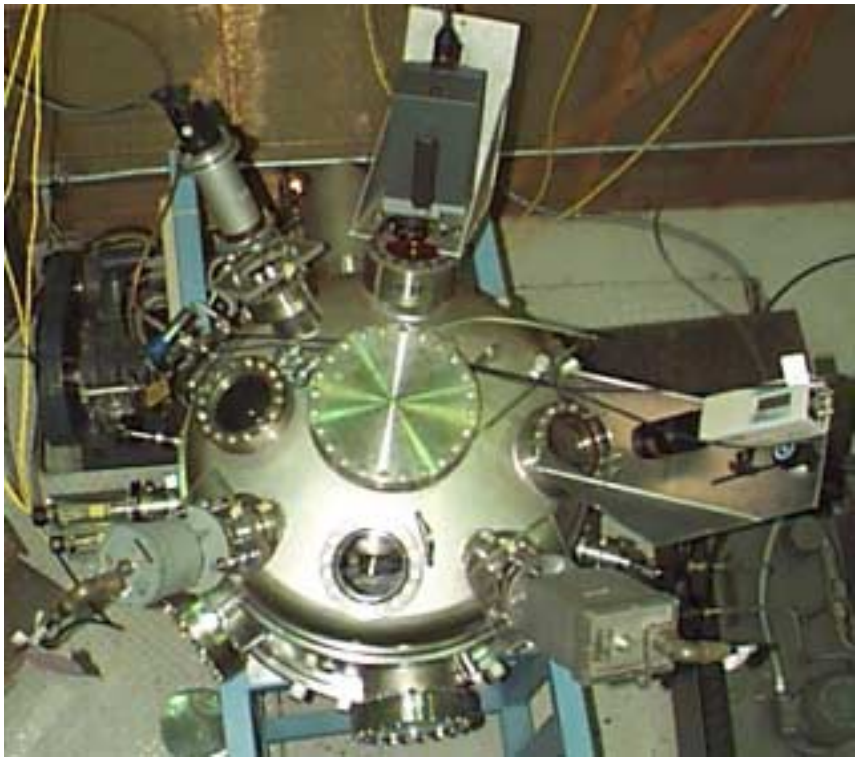
- **Surface**
  - **reflections of other sources (direct and secondary)**
    - **chamber wall reflectivity**
    - **filaments and heaters**
    - **plasma facing components**
  - **variations**
    - **contamination**
    - **phase change**
- **Optical path**
  - **diagnostic window transmission**
  - **gas / vapor absorption**
  - **ionized gas / vapor emission (e.g. Li emission at 2.44μm)**

IR Diagnostics Experiments

- **Gallium**
  - **Vacuum**
  - **Argon cover gas with windows**
  - **Argon cover gas without windows**
- **Lithium**
  - **Vacuum (data reported with estimated window transmission correction)**
- **Drude Emissivity Calculations**
  - **Based on free electron model ($\varepsilon=f[R_H,\rho_e,\theta,\lambda]$)**
  - **Wavelengths of detectors 2, 3, 3.9, 5 μm**
  - **Temperature range 30-390 C**

Test Configuration





Top View

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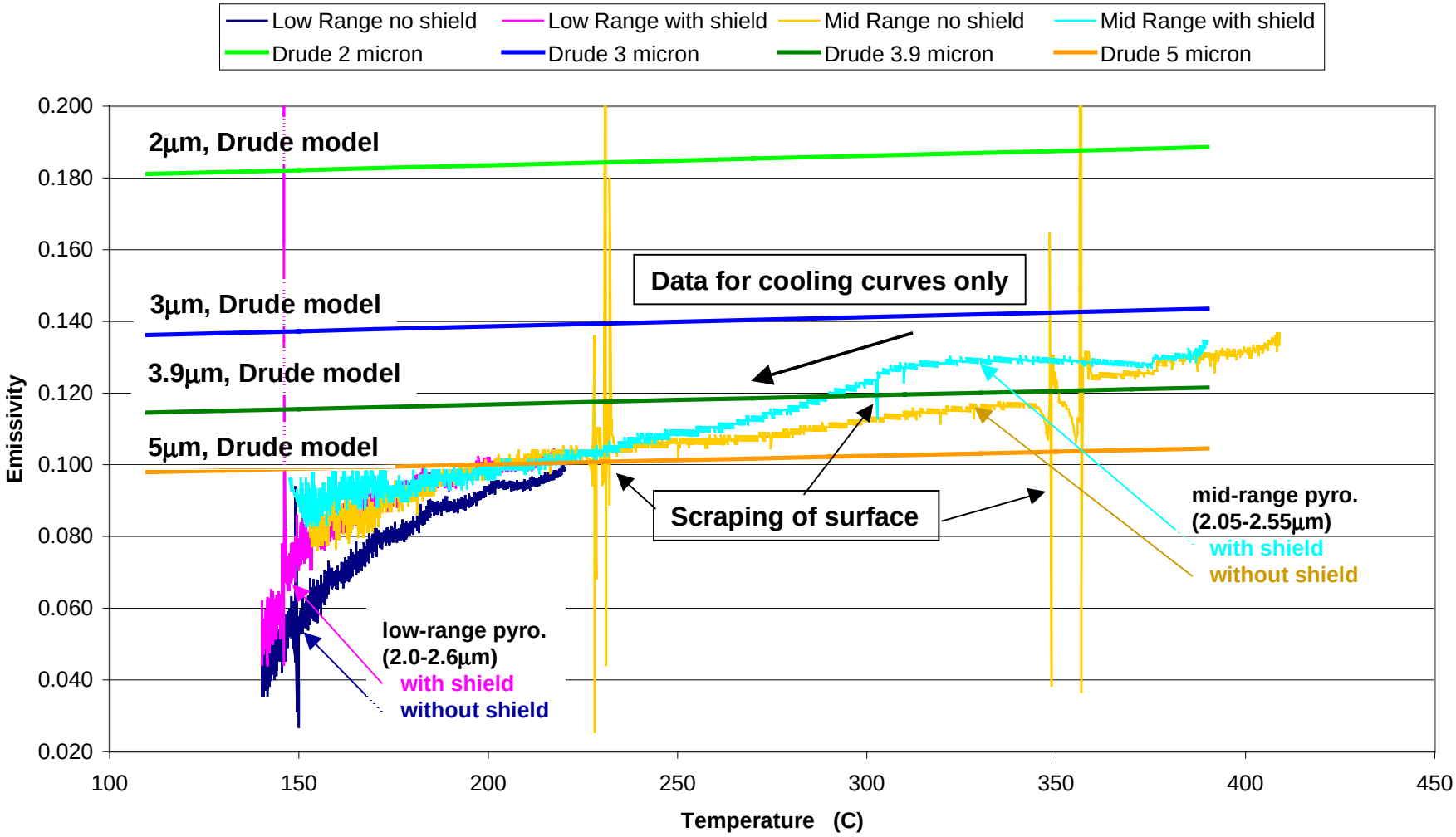
Instruments to Characterize Surface and Bulk Temperature

Name	*Temperature range (°C)*	*Wavelength (μm)*	*Emissivity Range*	*Windows*
Pyrometer (IRCON)	70–220	2–2.6	0.001 – 0.999	Sapphire
Pyrometer (Landmark)	130–550	2.05–2.55	0.1 – 1.0	ZnSe and WF Quartz
Pyrometer (IRCON)	300–1300	4.8–5.3	0.1 – 1.0	ZnSe and Sapphire
Infrared camera (Inframetrics)	25–500+	2-14 with 3.9 filter	1.0	ZnSe and NaCl, later, LW Quartz
Thermocouple (Type K)	0–1000	N/A	N/A	N/A

Gallium Apparent Emissivity

Argon cover gas

(no correction for gas absorption)



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Gallium Apparent Emissivity

Argon cover gas

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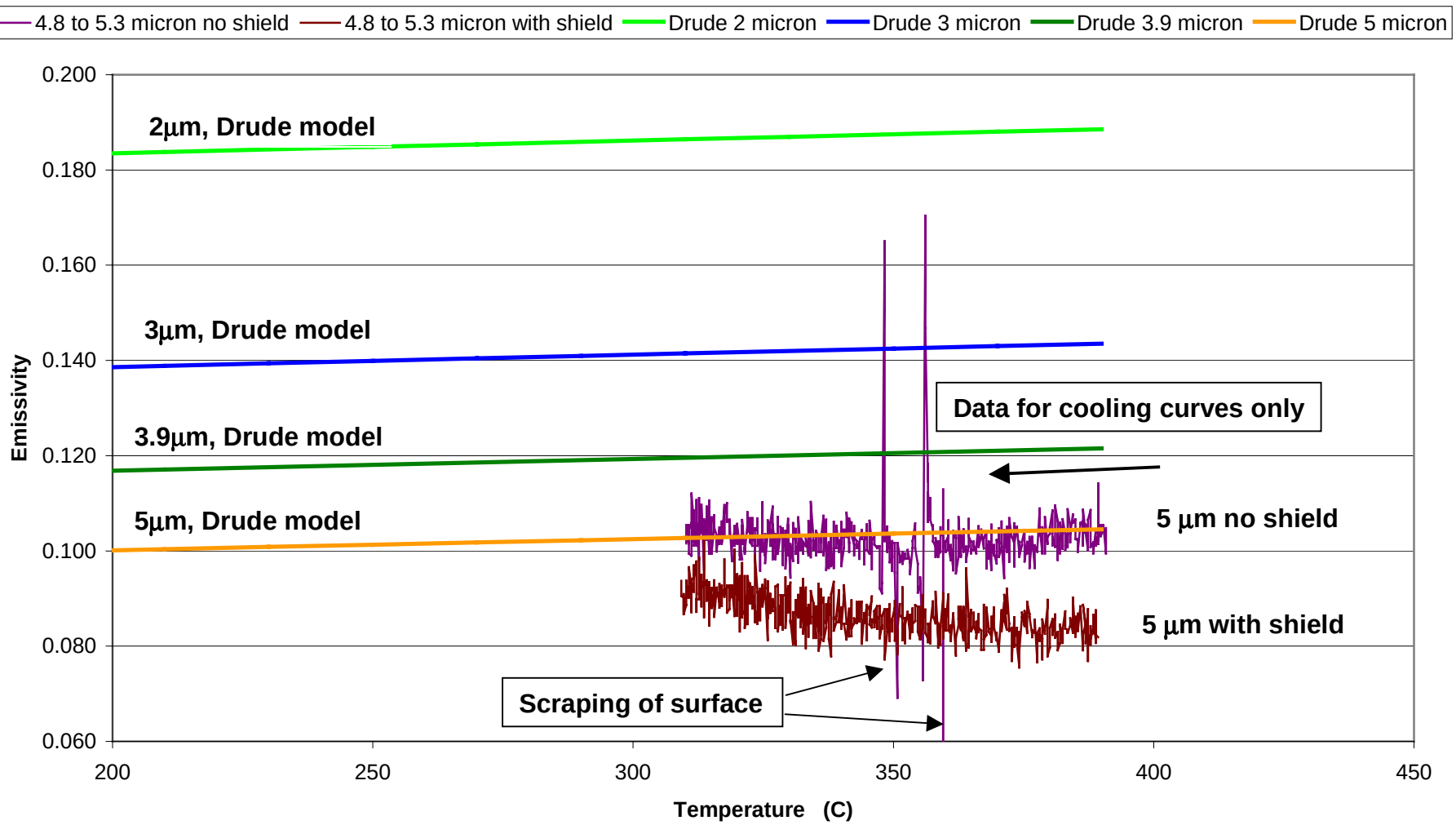

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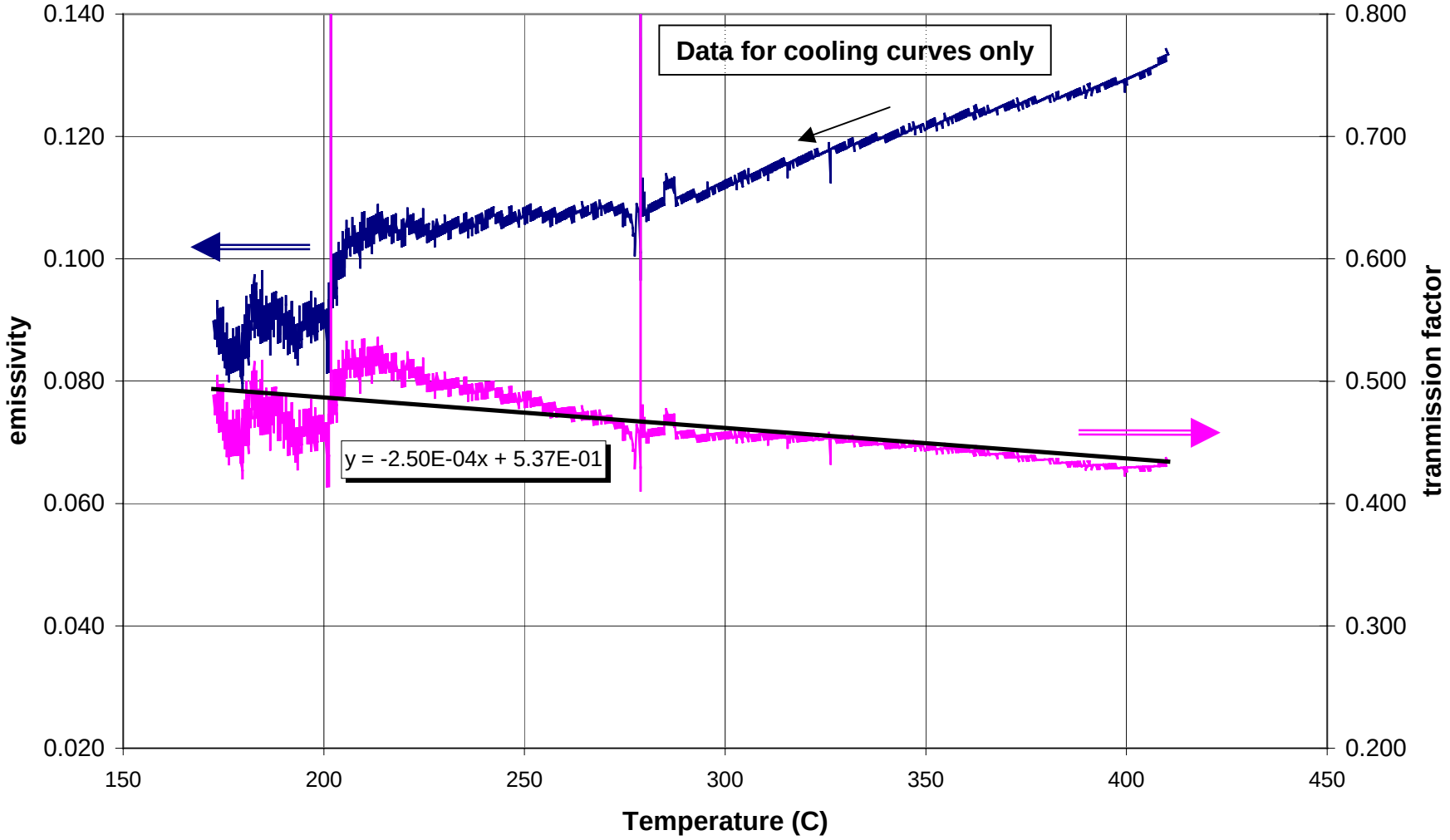
Gallium Corrected Emissivity and Window Transmission Factor
Mid Range Pyrometer (2.05-2.55 microns)



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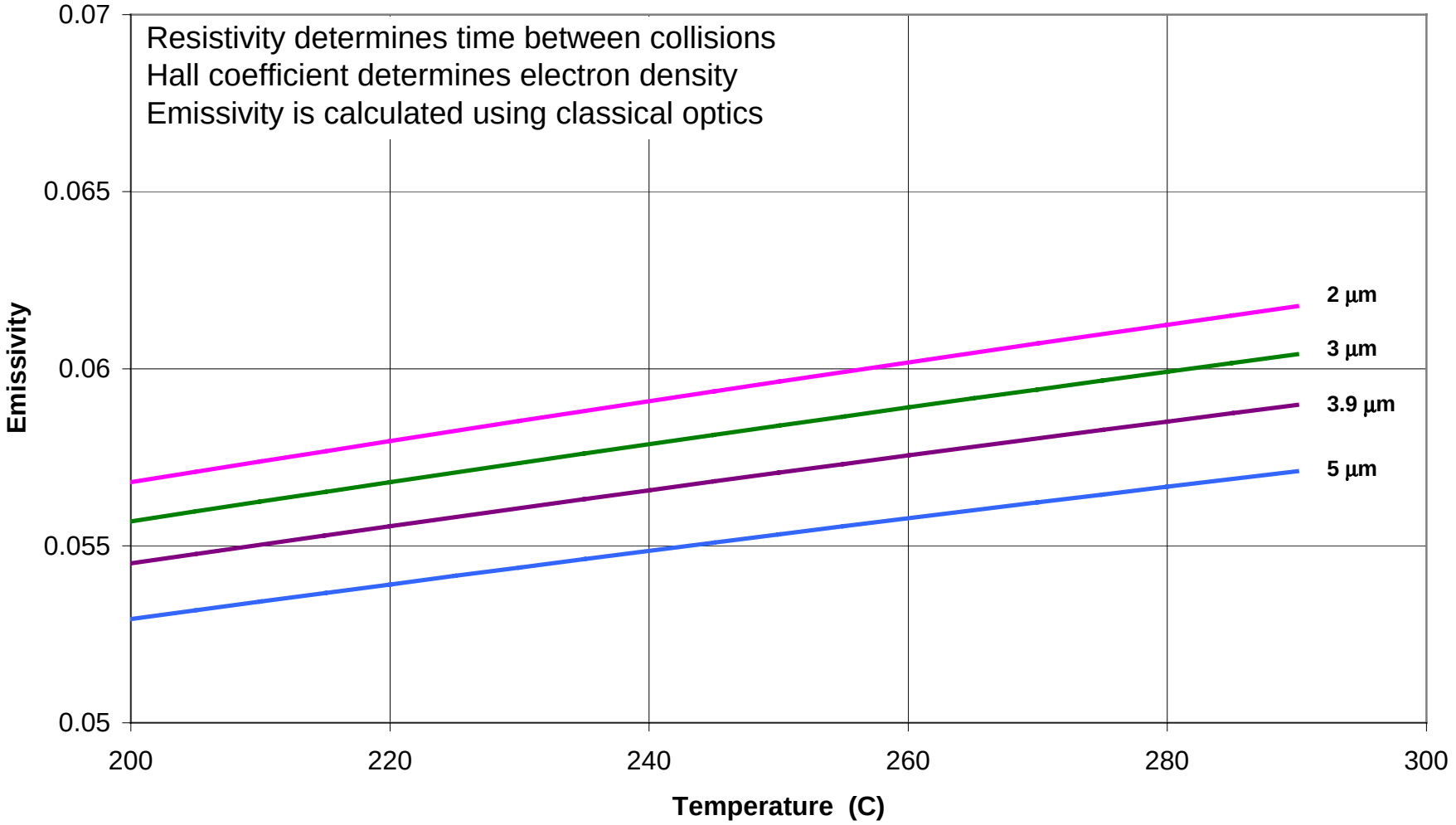
Emissivity of Lithium using Drude Model
40 degree angle of incidence



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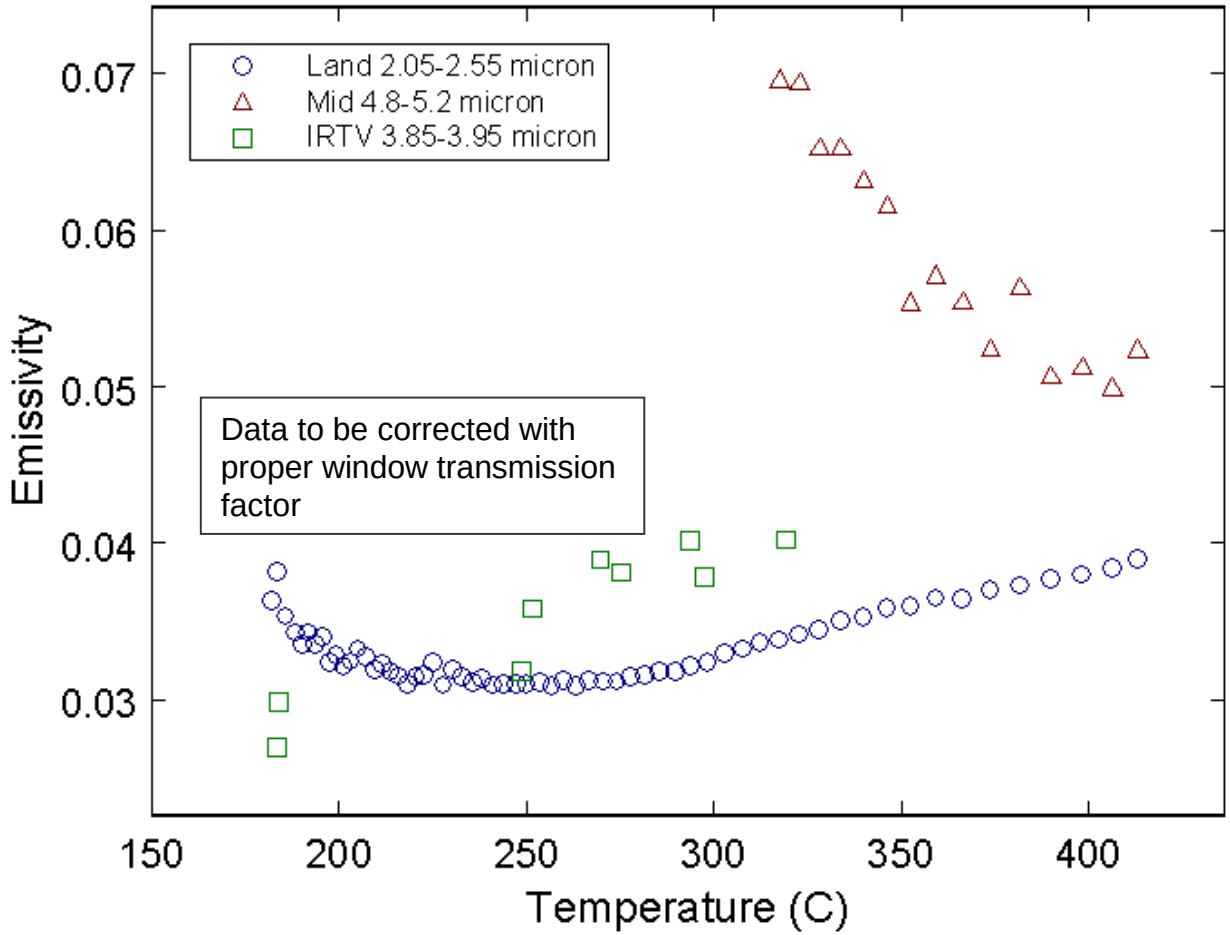
Liquid Lithium Emissivity Corrected Data (estimated window transmission correction)



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Conclusions

Commercial instruments may be usable for liquid metal temperature measurements with proper precautions and corrections.

Because liquid metals have such low emissivity, we need to:

- **control background IR radiation (reflections of other sources)**
- **determine and correct for transmission factors for windows, gasses and vapors**
- **control or account for contamination of liquid metal**

Future Work

- **emissivity measurements**
  - **Lithium and Tin**
  - **apply Gallium window transmission corrections to previous Lithium experiments**
- **build and operate a flowing liquid (Li,Sn) metal loop**
  - **emissivity measurements of flowing liquid metals**
    - **Lithium**
    - **Tin**
  - **application of heat flux with electron beam**
- **collaborate with others on heat transfer experiments**
- **collaborate with others in preparing LM modules for experiments in confinement devices (NSTX, C-MOD,..)**